Announcements

- Homework for tomorrow…

  Ch. 30: CQ 6, Probs. 10, 14, & 16

  29.26: $U_C(t) = (1.1 \times 10^{-3}\, t^2)$ J for $0 < t < 3$s

  $U_C(t) = (1.0 \times 10^{-2})$ J for $3\text{s} < t < 4$s

  29.29: a) $U_C = 1.1 \times 10^{-7}$ J b) $u_E = 0.71$ N/m^2

  29.60: 20 μF

- Office hours…

  MW 10-11 am

  TR 9-10 am

  F 12-1 pm

- Tutorial Learning Center (TLC) hours:

  MTWR 8-6 pm

  F 8-11 am, 2-5 pm

  Su 1-5 pm

Chapter 30

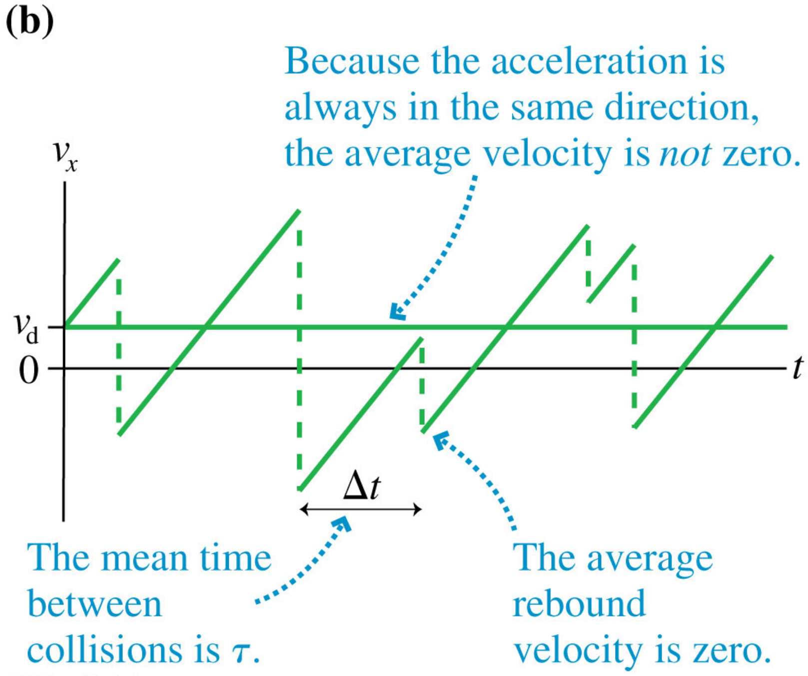
Current & Resistance

(*Current and Current Density & Conductivity and Resistivity*)

A Model of Conduction

Q: If there is a *non-zero E*-field, then there is a *non-zero F*, so shouldn't my electrons accelerate?

- instead of move at a *constant drift velocity*, v_d?



$m, e \longrightarrow F = eE$

$\sum \vec{F}_x = m\vec{a}_x$

$eE = m\vec{a}_x$

$\vec{a}_x = \frac{eE}{m}$

$\bar{V}$ = Avg Vel.

$V_{1x} = V_{0x} + a_x \Delta t$

$= V_{0x} + \frac{eE}{m}\Delta t$

Now calculate the drift speed, V_d, of the electron

$V_d = \bar{V}_{01x} = \bar{V}_{01x} + \frac{eE}{m}\bar{\Delta t}$

$= 0 + \frac{eE}{m}\bar{\Delta t}$

$\bar{\Delta t} = \tau \equiv$ (Avg. Time between Collisions)

$V_d = \frac{eE}{m}\bar{\Delta t}$

$V_d = \frac{eE}{m}\tau$

$i_e = n_e A V_d$

$i_e = n_e \frac{e\tau A}{m} E$

A Model of Conduction

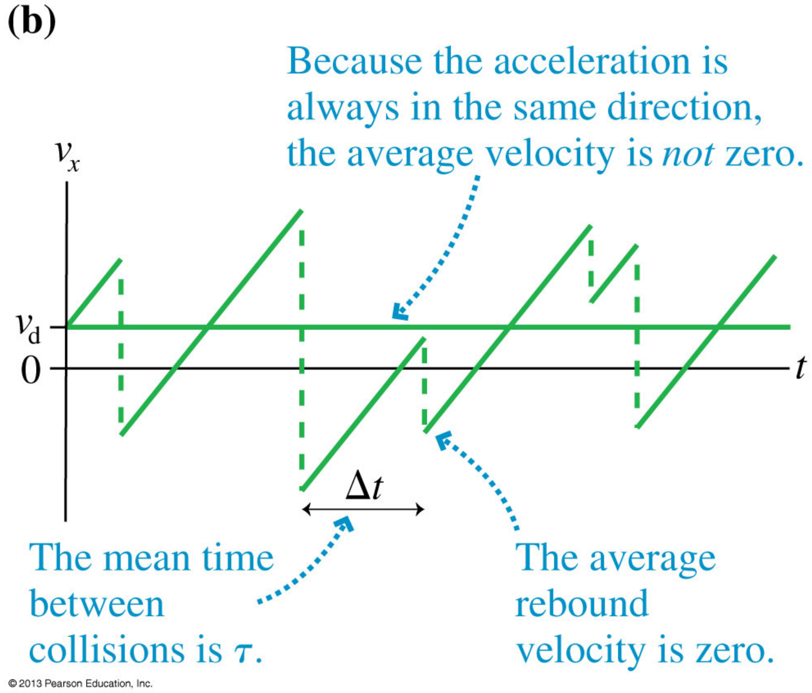
Q: If there is a *non-zero* E-field, then there is a *non-zero* F, so shouldn't my electrons accelerate?

- instead of move at a *constant drift velocity*, v_d?

$$\boxed{v_d = \frac{e\tau}{m}E}$$

so the electron current is..

$$\boxed{i_e = \frac{n_e e\tau A}{m}E}$$



i.e. 30.3: Collisions in a copper wire

i.e. 30.1 found the electron current to be 2.6 x 10^{19} s^{-1} for a 2.0 mm diameter copper wire in which the electron drift speed is 1.0 x 10^{-4} m/s.

If an internal *E*-field of 0.020 V/m is needed to sustain this current, how many collisions per second, on average, do electrons in copper undergo?

$$i_e = \frac{n_e e \tau A}{m} E$$

$i_e = 2.6 \times 10^{9}\ s^{-1}$

$V_d = 1.0 \times 10^{-4}\ m/s$

$E = 0.020\ V/m$

$R = 1.0 \times 10^{-3}\ m$

$A = \pi (1.0 \times 10^{-3}\ m)^2$

$$i_e m = n_e e \tau A E$$

$$\tau = \frac{i_e m}{n_e e E A}$$

$$V_d = \frac{eE}{m} \tau$$

$$\tau = \frac{m v_d}{eE} : \frac{9.11 \times 10^{-31}\ kg\ (1.0 \times 10^{-4}\ m/s)}{(1.6 \times 10^{-19}\ C)(0.020\ V/m)}$$

$$\tau = 2.8 \times 10^{-14}\ s$$

Collision rate $= \frac{1}{\tau}$

$\tau = 3.6 \times 10^{13}\ s^{-1}$

30.3:
Current and Current Density

Define the *current*…

$$\boxed{I \equiv \frac{dQ}{dt}}$$

For a *steady current*…

$$I = \frac{\Delta Q}{\Delta t}$$

SI Units?

$$[I] = \frac{C}{s} \equiv A$$

Amperes or “amps”

30.3:
Current and Current Density

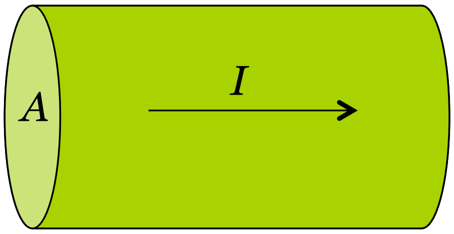
So, how is the *current* related to the *electron current?*

Current : Current Density

$I = \frac{Q}{\Delta t}$ $Q = N_e e$

$I = \frac{N_e e}{\Delta t}$

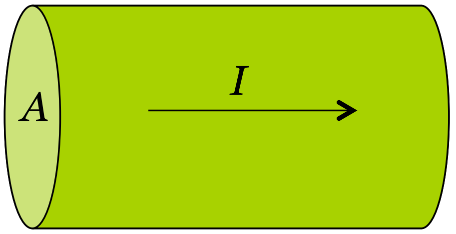
$I = i_e e$



30.3:
Current and Current Density

So, how is the *current* related to the *electron current?*

$$\boxed{I = e i_e}$$



Notice:

The direction of the current is *defined* to be the direction in which positive charges *seem* to move.

i.e. 30.4: The current in a copper wire

The electron current in the copper wire of i.e.'s 30.1 and 30.3 was 2.7×10^{19} electrons/s.

What is the current I?

How much charge flows through a cross section of the wire each hour?

$i_e = 2.7\times10^{19}\ 1/s$

$I = i_e e = (2.7\times10^{19}\ 1/s)(1.6\times10^{-19}\ C)$

$I = 4.3\ A$

$I = \frac{\Delta Q}{\Delta t}$

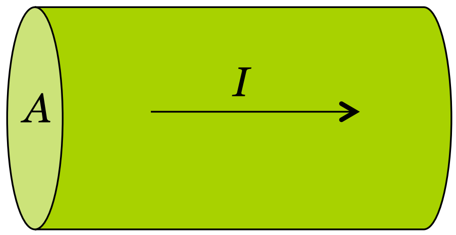
$\Delta Q = 4.3A(3600)$

$Q = 1.7\times10^{4}\ C$

30.3:
Current and Current Density

Define the *current density*…

$$J \equiv \frac{I}{A}$$



Electron current in a wire of cross-Section A is

$$i_e = n_e A v_d$$

SI Units?

$$[J] = \frac{A}{m^2}$$

$$I = i_e e = n_e A v_d e$$

$$J = \frac{n_e A v_d e}{A}$$

$$J = n_e e v_d$$

30.3:
Current and Current Density

The *current density* in a wire…

$$\boxed{J \equiv \frac{I}{A} = \eta_e e v_d}$$

i.e. 30.5: Finding the electron drift speed

A 1.0 A current passes through a 1.0 mm diameter aluminum wire.

What are the current density and the drift speed of the electrons in the wire?

$i_e = 30s$

$I = 1.0\,A$

$R = 5.0 \times 10^{-4}\,m$

$n_e = 6.0 \times 10^{28}\,\frac{1}{m^3}$

$J = ?$

$v_d = ?$

$J = \frac{I}{A} = \frac{I}{\pi r^2} = 1.3 \times 10^6\,A/m^2$

$J = n_e e v_d$

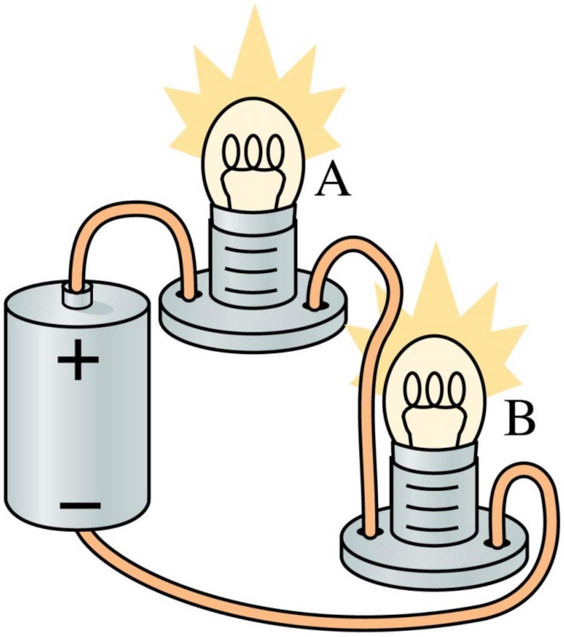
$v_d = \frac{J}{n_e e} = \frac{(1.3 \times 10^6\,A/m^2)}{(6.0 \times 10^{28}\,m^{-3})(1.6 \times 10^{-19}\,C)}$

$v_d = 1.3 \times 10^{-4}\,m/s$

Quiz Question 1

A and B are identical light bulbs connected to a battery as shown.

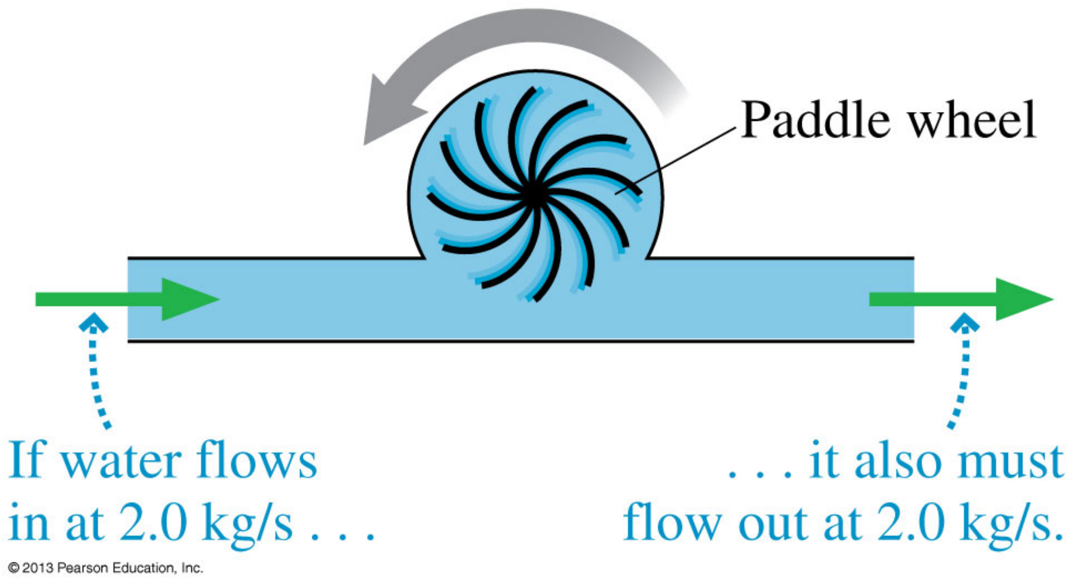
Which is brighter?



1. Bulb A.
2. Bulb B.
3. The bulbs are equally bright.

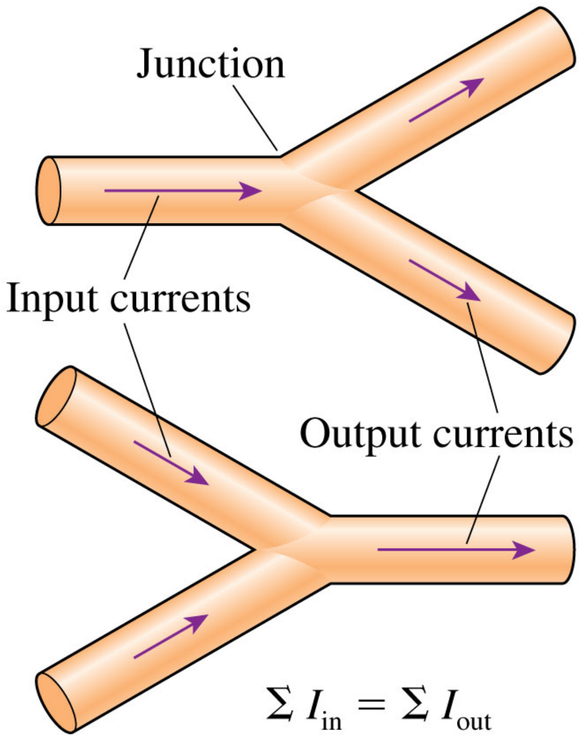
Conservation of Current

H_2O Pipe Analogy:



Conservation of Current

- The rate of electrons leaving a light bulbs is *exactly the same* as the rate of electrons entering the light bulb.
- The current does NOT change!

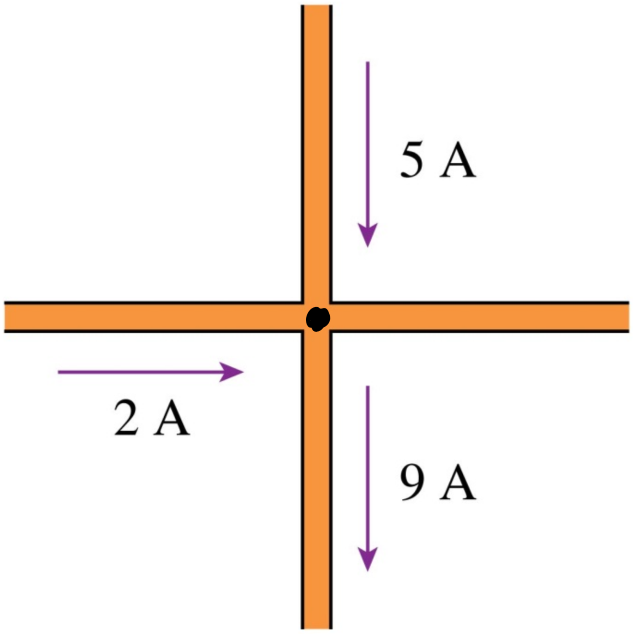


Kirchoff's Junction Rule

$$\boxed{\sum I_{in} = \sum I_{out}}$$

Quiz Question 2

The current in the fourth wire is



1. 16 A to the right.
2. 4 A to the left.
3. 2 A to the right.
4. 2 A to the left.
5. Not enough information to tell.

30.4:
Conductivity and Resistivity

How is the current density, J, related to the E-field driving the current?

30.4: Conductivity and Resistivity

How is the current density, J, related to the E-field driving the current?

$$\boxed{J = \sigma E}$$

where $\sigma = \dfrac{n_e e^2 \tau}{m} = \text{conductivity}$

30.4:
Conductivity and Resistivity

How the current density, *J*, is related to the *E*-field driving the current:

$$\boxed{J = \sigma E}$$

Notice:

1. *Current* is caused by the *E*-field exerting forces on the charge carriers.
2. The *current density* (& *current*) depend *linearly* on the *strength* of the *E*-field.
3. The *current density* also depends on the *conductivity* of the material.